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I. Scope

1. This Note is concerned with the measures that can be taken during the planning of new or redeveloped hospitals to restrict the creation and transmission of noise. It also gives guidance on the choice and installation of plant and equipment from the noise control aspect.

2. The design specifications for the standardised components recommended by the Inter-Board Study Groups for use in the Industrialised Hospital Building Programme are in line with the recommendations made in this Design Note. Many components are already available and the range is continuously being extended.

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II. Introduction

General

3. Despite measures taken by hospital authorities and staff the noise level in hospitals has risen rapidly in recent years. Some of this rise can be attributed to the increasing volume of outdoor noise, but the level of internal noise has also been growing through the increased use of mechanical and mobile equipment, and the provision of radio and television. The increasing size of hospitals also complicates the problem of noise control and in the large district general hospital offering a wide range of specialist services, noise control becomes both very complex and very necessary. For hospitals situated in centres of urban areas, near main roads, or near airports, the problem becomes even more acute.

4. To some hospital patients a quiet environment may be essential for recovery: for all acutely ill patients such conditions are clearly desirable. Quiet conditions are desirable also for staff both in their working environment, e.g. in consultation and examination rooms, and in their residential accommodation. Today, treatment and nursing of patients is generally more intensive than previously. There is thus greater activity which gives rise to more noise. This is unavoidable, but with forethought and self-discipline staff can keep this to a minimum. It is necessary for patients and visitors also to appreciate the need not to create unnecessary noise.

5. For easy reference, an explanation of the terms used in this Note is included in Appendix I. Sound (noise) levels are indicated in decibels. An increase of 3 dB is approximately equal to a doubling of the sound energy. Thus a sound of 60 dB has roughly twice the energy of one of 57 dB. On the other hand most people judge that, roughly, an increase in noise of approximately 10 dB sounds twice as loud although the energy increase is actually tenfold. The normal range of audibility is 0–130 dB: zero on the scale per sound in air corresponding to a pressure of 0.0002 dynes per square centimetre. A change of 1 dB is barely perceptible to the normal person while a change of 3 dB in a meter reading is about the smallest increment that most people would consider significant. An overall measurement of sound pressure level in dB is not necessarily a reliable guide to the subjective noise level since the ear is much more susceptible to sounds of some frequencies than to those of others. It is necessary to add weightings to the readings of sound pressure level meters (which would otherwise measure sound pressure levels of different frequencies on equal scales) to compensate for the varying susceptibilities of the human ear, and thus to produce readings which more accurately reflect the effect on the ear of the sounds registered by the meter. Such an instrument is known as a sound level meter and has three pre-selected weighting contours, A, B and C. The most usual scale of weightings is the A scale, which is adopted here: readings on meters so weighted are given as dBA. Some examples of readings in dBA are given in Appendix II (see paragraph 11).

6. Much valuable information in the subjects covered in this Note is to be found in British Standard Code of Practice; C.P.3 Chapter III (1960): Sound Insulation and Noise Reduction.

7. Three approaches to noise control are discussed in this Note:

A. Planning considerations
B. Constructional techniques
C. Control of noise at source

These considerations are inter-dependent, however, and the degree of protection afforded by any one will reduce correspondingly the need to take other types of precautions. Important as noise control is, it must be recognised that it will sometimes have to be subordinated to other needs such as operational convenience. This makes it all the more important to make, both at development control plan (stage B) and sketch plans (stage C) an estimate of the potential noise nuisance to patients and staff. If this is done and the potential sources of noise are identified it may be possible to plan so as to achieve the necessary reduction in noise simply and within the cost allowances for hospital building. If such consideration is not given at these early stages and the conclusions incorporated in the working drawings, the result may be a noise level which is permanently distressing to patients and staff, and considerable further expenditure, which could have been avoided, may be needed on palliative measures.

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8. Appendix III refers to some sources of noise and suggests the stages at which these should be investigated for a new hospital development.

III. Methods of noise control

A. Planning considerations

9. The noise level within a building will depend both on the noise entering it from outside (exterior noise) and on that generated within the building itself and transmitted through the building (interior noise).

Exterior noise

10. This may be classified as being from sources outside or inside hospital precincts. Examples of the former are noise from road traffic, railways, road works, and, in some locations, football grounds, race tracks, building operations, industry and aircraft: examples of the latter are noise from ambulance bays, car parks, unloading bays, boiler houses, workshops, laundries, kitchens, and from heavy equipment of all types. (Some of the sources listed may form an integral part of a building, and they may generate noise which, being transmitted through the building structure itself, is therefore strictly interior noise). Areas which are sensitive to exterior noise will always include wards, operating theatres, delivery rooms, treatment rooms, examination and consulting rooms, and staff sleeping areas.

11. In the great majority of cases, particularly in urban areas, most noise from outside the hospital sites will be generated by road traffic. The table in Appendix II indicates the range of noise levels at locations in which road traffic noise predominates. Sites in towns on cross roads or on hills are usually particularly noisy, as are sites abutting on to busy main streets of continuous high buildings—which cause noise to reverberate. The value of building high in order to escape from noise generated at street level has often been over-rated. It appears that whilst traffic noise will disturb occupants of the first two stories of a building more than those above, noise does not diminish appreciably with further increases in height above the third floor. Aircraft and railway noise, whilst more intermittent than road traffic noise, is often of higher intensity. A large transport aircraft about 2½ miles from take-off will create a noise level of around 100 dBA directly below its flight path. When sites for hospital projects are being considered it should be ascertained what are the frequency, type and noise levels of aircraft, whether extensions are likely to be made at local aerodromes, whether flight paths are likely to be altered, what areas are likely to be allocated for maintenance testing and their noise level. Electric trains will produce an overall noise level of around 70 dBA at a distance of 100 feet. Railway cuttings reduce the spread of noise whereas embankments and viaducts or steel bridges extend it. The noise produced by factories and commercial concerns must also be considered; of the commercial concerns which are particularly noisy, milk distributing centres and open multi-storey car parks might be noted.

12. Noise from the type of source described in paragraph 11 can be assessed comparatively easily and it is one of the factors which should be taken into account when choosing a hospital site. Distance provides some defence against noise and a site as far away from outside noise sources as is possible should be chosen if other relevant considerations permit. Within the selected site, buildings should be placed so that noise sensitive areas are removed as far as practicable from exterior noise sources, and are screened by less sensitive departments. Screening by means of walls and artificial mounds in the hospital precincts can be of some use, particularly in reducing high frequency sounds. Advice on the calculation of the value of screens is given in Appendix B of British Standard Code of Practice; C.P.3: Chapter III (1960). Thick belts of strong, leafy mature trees such as oak, limes or planes together with evergreens and conifers, can also be of use. Siting should take advantage of existing tree belts, but not rely on newly planted trees to act as a screen, for unless these are mature transplants they will provide no protection for many years. Grass rather than hard paving should be laid wherever it is a possible alternative.

13. As stated in paragraph 10, exterior noise is also produced through the activity of the hospital—by ambulances, motor cars and service vehicles, fuel and stores deliveries (e.g. medical gas cylinders), refuse collection, and the movement of goods about the hospital. Delivery of milk bottles is a common cause of complaint, and careful siting of service areas and their approaches away from the noise sensitive areas can do much to reduce the nuisance of unavoidable noise. Certain departments of the hospital can also become considerable noise sources (e.g. boiler houses, laundries, workshops and kitchens). The need to protect sensitive areas from these sources is one factor to be taken into account in preparing a development control plan. Where noisy departments do not need to be part of the main hospital building, it may be advisable to group them into a separate service area, carefully sited so that noise is minimised. The measures described in paragraph 12 apply to exterior noise created on the hospital site insofar as this is compatible with the efficient running of the hospital. Measures against internal transmission of noise from hospital sources are described in later paragraphs.

14. Noise from construction and demolition sites can

cause great disturbance and can be particularly troublesome where hospital developments are phased. There is increasing consciousness in the construction industry of the annoyance and disturbance caused by noise from building sites, and measures are taken to reduce it by silencing and suppression of noisy plant, provision of screens and hoardings, and good site planning. The best current practice should be emphasised in any contract. Appendix IV gives a table of typical noise levels of contractors' plant.

15. The architect and engineer can contribute by evolving designs that require less noisy construction processes. The layout of the site is also important and best use should be made of natural features to shield existing working areas of a hospital from neighbouring developments.

16. Studies are needed in order to arrive at acceptable standards of noise in relation to hospital patients and staff. One such study is being undertaken on behalf of the Ministry of Health at University College, London.

Interior noise

17. Where noise-creating departments are part of a main building, care must be taken to separate them as far as possible from sensitive areas, such as wards. In particular, when the main kitchen, which is a constant source of both impact and airborne noise throughout the day, has to form part of the main complex it should preferably be sited below, and not above, sensitive areas to facilitate the insulation of equipment and machinery and to reduce the spread of impact noise.

18. Within ward units, much noise is generated from the ancillary rooms. These rooms, being frequently in use, tend to have constantly open doors. Some form of noise baffling between open wards and rooms of this kind is desirable. Central dish-washing and sterilisation facilities can do much to reduce noise generated within ward units. Special attention must be paid to both siting and internal planning of units such as children's wards and out-patient departments, parts of which are generators of noise and parts of which require protection from noise. It has been found for example that the noise level in the nursery of a maternity hospital can be as high as 80 dBA at night. Noise can easily spread through a building via the corridors and the use of sound absorbent ceilings will help to reduce this transmission (see paragraph 48).

B. Constructional techniques

General

19. As has been suggested above, the most efficient way of combating noise is to plan to avoid it. But the planning of a hospital is shaped by many factors and the most desirable requirements from the point of view of protection from noise will frequently have to be subordinated to other competing requirements, such as the need to place hospitals within busy urban areas, or to establish the most efficient juxtaposition of rooms and departments for nursing care or for service deliveries. The greater the extent to which planning requirements for noise control have to be sacrificed, the greater will be the need to provide adequate constructional protection: and the more difficult it will be to provide such protection.

20. Constructional means, properly applied, can prove most effective even in potentially very difficult situations.

21. It is important to distinguish between the functions of sound absorption and sound insulation. The former is a quality dependent on the nature of the surface of a material and will determine the degree to which sound, on striking the surface, will be absorbed or reflected. Sound insulation is the prevention of the transmission of sound through a barrier (e.g. wall, ceiling, floor); the degree of sound insulation obtained will be dependent on the construction of the barrier. There is no direct and necessary relation between the sound insulation value of a partition and the sound absorption values of its surfaces. Insulating materials are used to prevent the spread of noise from one room to another; and sound absorbents to control reverberant sound within a room.

(1) *Principles of sound insulation*

General

22. The degree to which a partition, when considered alone and under certain standard conditions, provides sound insulation is known as its sound-reduction factor, measured in decibels (dB). When sound-reduction factors are quoted the figure is usually the average of the sound-reduction factors at all frequencies between 100 and 3,200 c/s—the most important frequency range as far as sound insulation problems are concerned in hospitals.

23. Sound can be transmitted either through the air or through a structure, and can be classified as (*a*) airborne or (*b*) impact according to whether it is (*a*) generated in the air or is airborne before reaching a structure providing protection for a "noise sensitive" area, or (*b*) is caused by blows on the protecting structure itself. The type of protection needed will vary according to the nature as well as the magnitude of the sound.

Insulation against airborne sounds

24. Airborne sound exists as a vibration; the heavier the barrier through which sound passes the greater will be its reduction, since there will be more resistance to it; but the efficiency of sound insulation depends not only on weight but also on the completeness and uniformity of the barrier. Areas of weak insulation within a barrier (such as a door in a partition) will have a marked effect on the efficiency of the barrier as a whole (this aspect is discussed more fully in paragraph 30). Sound insulation, particularly in lightweight partitions, is also affected by the "stiffness" of the material; flabby materials consisting of heavy particles weakly held together will form more effective insulators than stiffer varieties. The stiffness referred to here is the stiffness of

the barrier as a panel, not the rigidity of the edge fixing; as a rule, firm fixing at the edges is an advantage.

25. Sound insulation can also be achieved by a "discontinuity" or separation of the parts of a structure. The principle behind discontinuous structure is to allow one structure to vibrate without too much disturbance of any neighbouring structure by providing a cushion of air between the two structures (or in the case of floating floors a resilient cushioning material) and a restricted number of fixed links between the two structures. However a narrow enclosed volume of air gives only a moderate degree of cushioning, particularly against low frequency sounds, and cavities in discontinuous constructions should be as wide as possible. All walls give better insulation of high than low frequency noise. For a given weight of partition, cavity wall construction gives higher insulation at the middle and high frequencies than that given by a single leaf construction, but not at the low frequencies unless the spacing is large (6–8 in. or more).

Insulation against impact sounds

26. Impact insulation is best provided by a resilient layer, for example carpet in direct contact with the impacting force. For functional reasons it may be necessary to provide the resilient layer under a harder wearing surface (e.g. foam-backed plastic sheet) the surface layer being in the form of a raft. Much more resilience is needed under a floating raft than is needed in a direct floor covering to gain comparable sound reduction. Unfortunately a material such as carpet which effectively reduces impact sounds will not provide good insulation against airborne sound and conversely increasing the weight of a floor will not necessarily improve its ability to reduce impact noise. Equally the noisiness of a floor for walking on should not be confused with its efficiency for impact insulation—a wooden raft may be noisy to walk on but will provide a good reduction of noise transmitted to the floor below.

Direct and indirect sound transmission

27. Sound is transmitted between rooms both directly by the shortest route—for example, through a partition between the source and the receiving room—and indirectly, by any other path such as windows, flanking walls, or corridors. It is essential to know the relative amounts of sound transmitted via the direct and indirect paths if appropriate sound insulation measures are to be taken. The weaker path is always the critical one.

(2) *Application of sound insulation**

General

28. The great variety of departments or units in hospital, each with different requirements for quiet and with varying potentialities for making noise, makes it possible to give only general guidance on insulation values. It is recommended for most situations that walls or partitions should have an insulation value of at least 40 dB—i.e. a sound passing through the wall or partition will be reduced by 40 dB. Higher values of insulation—45–50 dB are recommended where a noisy room is adjacent to one where quiet is essential. Higher values than this can only be obtained at considerable expense through such measures as completely "isolating" rooms—making a room completely discontinuous with surrounding areas.

29. Most of the best sound insulating materials (e.g. concrete, brick) are incombustible and, therefore, present no fire hazard. Reference should be made to Hospital Design Note No. 2, Protection against Fire.

30. The effect of windows, doors, and other openings in walls and partitions must always be borne in mind. A good sound insulation barrier can easily be lost if the effects on insulation of openings incorporated in walls are not properly appreciated. For example, the incorporation of a six-inch square ventilator hole (insulation 0 dB) in a brick wall (insulation 50 dB) of 250 sq. ft. area results in a loss of 20 dB from the insulation value of the complete brick wall, leaving a net insulation value of only 30 dB. The insulation can, of course, be improved by the introduction of attenuators in the hole or duct. If half of any wall has an insulation value less than the other half (e.g. a wall with 50 per cent window) then the net insulation value cannot be more than 3 dB above the lower insulation value, regardless of the upper insulation value. The tables at Appendix V illustrate the effect of different types of windows and doors on the insulation values of walls and partitions. Decisions taken regarding the required or desirable insulation value of walls and partitions must always be made with full knowledge of the openings contained within them.

Doors

31. Doors should be solid (4–5 lb per sq. ft.) and must be close-fitting in their frames but if there are edge gaps the insulation can be 6 or more dB lower. A heavy well-fitting door in a partition providing 40 dB will give an overall insulation of 35 dB. Higher insulation values for a single door cannot be obtained without the use of expensive "refrigerator" methods of closure. Double swing doors, whilst they may frequently be necessary in hospitals, have little insulation value because of the air gaps round the doors. The fitting of an edge sealing of rubber or plastic will increase the insulation value. Automatic door closers, rubber or plastic gaskets and stops can help to ensure quieter operation of doors; the former also help to make the door a more efficient sound barrier. Quiet action latches are also necessary. P.V.C. and rubber doors can be quiet in operation but have little insulation value due to air gaps and low weight. If rooms requiring quiet have to be sited near noisy areas, it may be necessary to screen the quiet area by providing an extra door with a baffle lobby lined with absorbent material. This can provide an insulation value of up to 40 dB. If space does not permit the construction of a lobby in conditions where a door or

*For further information see Building Research Station Digests No. 88 Revised March 1964, No. 89 Revised January 1963, Addendum June 1964.

doors of high insulation value are needed, twin doors may be fitted, either single or double; these doors should, however, always be more than 4 inches apart and as much sound absorbent material as possible should be introduced into the air space: if the air space is narrow at least one door surface should be covered by the treatment. It should be possible in this way to provide an insulation value of 35 dB.

Windows

32. Appendix VI gives a table of the insulation values of different types of windows against admission of exterior noise. It will be seen that the degree of insulation of single windows is comparatively small particularly if windows are open. These figures show the importance of planning and the need to consider noise at development control plan stage. Sealing or double glazing increases the insulation and may be suggested. The following factors should be borne in mind. Double windows are of little value unless the air space between the glass is at least 8 in., but a width of 12 in. is preferable and as much sound absorption lining as possible should be provided in the air space. If one set of glazing in a double window is efficiently sealed there is no objection to the other set of windows being openable for cleaning etc. purposes, providing the openable window is tightly fitting. If the sealed window is on the outside, there is in principle a possibility of condensation, particularly in those parts of the building where high humidity conditions exist. However, in departments without high humidity that are constantly heated the occasions when condensation will occur are likely to be infrequent. The use of sealed windows will require the provision of mechanical ventilation.

33. When adjoining rooms have adjacent windows open, the sound reduction from one to the other will be limited to about 30 dB regardless of the nature of the partition wall; if one window is closed the figure rises to about 50 dB and if both are closed, about 60 dB (varying according to the distance between windows). It is, therefore, important that opening lights are not designed so that they are adjacent to and very close to those of adjoining rooms.

Walls and partitions

34. Generally the sound reduction between rooms should be 40–45 dB. Sound insulation of this degree can be provided by:

(*a*) Solid construction
(*b*) Cavity construction
(*c*) Wall linings

(*a*) *Solid construction*

35. Solid construction of walls and partitions provides the most efficient means of noise reduction; a 4½ in. brick wall with ½ in. plaster both sides or an 8 in. hollow dense concrete block with ½ in. plaster both sides, provide a reduction of about 45 dB. Partitions of 3 in. clinker block plaster both sides have an insulation value of at least 40 dB and, from the noise reduction aspect, are suitable for use in hospitals.

(*b*) *Cavity construction*

36. Cavity construction can be of benefit when used in conjunction with lightweight materials but to be effective the design should incorporate a fairly large area uninterrupted by any rigid connections, say, not less than 100 sq. ft., and the width of the cavity must be at least 2 in. to provide insulation against an average range of frequencies—widths of up to 12 in. are desirable.

37. It will not be worthwhile to include sound absorbing blankets within cavity constructions if the surface of the cavity is itself sound absorbent—e.g. clinker blocks. However, when the surfaces to the cavity are hard, blankets will usually be beneficial.

38. Insulation values of cavity walls and solid walls are given in Appendix VII. It should be noted in measuring the sound insulation of single solid partitions in buildings of traditional construction that there is usually little difference between laboratory and field results. However, with more complex type partitions in dry construction the results obtained in the laboratory are usually better than those measured in the field. This applies particularly with partitions of insulation values of 40 dB or higher. The difference in results may be due to several factors such as flanking transmission, the structure, edge fixing, air gaps, etc. which may all reduce the insulation value of the partition. The insulation values recommended in this report are finished building requirements and it is therefore important to know whether insulation values quoted for partitions are those obtained in the laboratory or in the field. If the former, it is wise to assume that the insulation value in practice will be several dB less. The figures given in Appendix VII are all field measurements except for the last two items.

(*c*) *Wall linings*

39. Comments made on cavity walls also apply to wall linings and, as with cavities, wall linings are more useful on light than on heavy walls.

40. Folding/sliding partitions can possess good insulation qualities only if fitted to extremely close tolerances. If folding/sliding partitions have to be used in hospitals —as might be the case occasionally in staff common rooms or dining rooms—consideration should be given to the use of the partitions designed for schools by the Department of Education and Science in conjunction with the Building Research Station, which have a 24 dB value for single partitions and 38 dB for double partitions with 8 in.–12 in. air space. Linings should be flexible but not porous and should be as heavy as possible.

41. Where suspended ceilings are used care must be taken to ensure that the effectiveness of the partition as a

barrier to noise is not inadvertently lost. In other words the insulation-path through the ceiling of one room via the ceiling space and down through the ceiling of the adjacent room is as effective as the partition itself, i.e. has an insulation value of 40 dB. To achieve this the ceiling should be air-tight and the membrane be not less than 5 lb./sq. ft. Alternatively where the ceiling membrane is light-weight (less than 5 lb./sq. ft.) the partition should be carried through the ceiling to the structural slab, or the space above the partition should be filled with a continuous carefully fitted barrier along the line of the partition. With many types of suspended ceiling, plasterboard with all joints sealed usually forms a sufficient barrier. Any pipes that pass through the partition or the barrier should be packed around with a suitable sound absorbent material to prevent transmission of sound.

Floors

42. Particular attention must be paid to the insulation value of floors, especially those between the noise creating parts of the building and wards. Floors should be considered together with ceilings to ensure that the needs of sound insulation and other requirements are met in the most economical way. For floors an insulation value at least equal to Grade I for flats, as set out in Appendix C of B.S.C.P. C.P.3: Chapter III (1960), is required and this will often mean solid floors with floating finishes. Grade I insulation can be achieved by a concrete floor and a floating concrete screed with any surface finish, or a concrete floor with a 2 in. light-weight concrete screed and floor finish of p.v.c. on sponge rubber underlay. A heavy concrete floor (75 lb/sq. ft.) covered in a similar way to the above would need no floating screed.

43. Concrete floating screeds or timber rafts should be separated from the floor by resilient quilts of fibre-glass, or mineral-wool or equivalent. The minimum thickness of concrete should be 2½ in. Curling of concrete floors may occur at the edges of areas greater than 150–200 sq. ft. In these cases it is safer to use a synthetic anhydrite screed instead of cement. The screed thickness may be reduced to 1¼ in. For further information on floors and insulation see Building Research Digest No. 89 (Revised Jan. 1963 with addendum of June 1964).

44. Floating floors should be self-contained within each room; on no account should partitions be built on top of a floating floor as this will reduce its insulating quality, and cracking in the partition may be caused as the floor moves.

Ceilings

45. Suspended ceilings can be used to raise the insulation value of concrete floors not covered by floating screeds. If suspended ceilings are combined with suitable floor finishes—such as p.v.c. on a very resilient underlay—the insulation value of the floor can be equal to Grade I. If suspended ceilings are used to bring the floor insulation up to Grade I the following criteria should be met:

(i) The ceiling membrane should be fairly heavy—not less than 5 lb/sq. ft.

(ii) Direct sound penetration via air paths, such as would occur with ceilings of open-textured or open-jointed materials, should be eliminated.

(iii) The points of suspension from the floor structure should be as few and as flexible as possible.

(3) Principles of sound absorption

46. The distinction between sound absorption and sound insulation has already been made. In that sound absorbents can reduce the reverberant levels of noise on the source and receiving side of a partition, they affect the noise reduction between rooms but the reduction due to absorption is usually so small that it is not significant. Generally the use of sound absorbents is to reduce the noise level in the room where the sound is generated.

47. Doubling the amount of absorption reduces the energy by 3 dB, and doubling again gives another 3 dB reduction. The efficiency of sound absorption of any particular treatment varies with frequency though normally absorbents will have to combat a wide range of noise frequency. Single figure noise reduction co-efficients are often quoted for absorbents—calculated by taking the average of the absorbent co-efficients at 250 c/s, 500 c/s, 1,000 c/s and 2,000 c/s; these values cover the range of most general noises but not the frequency band where the ear is most sensitive which is around 4,000 c/s. It may be advisable to examine the co-efficient at 4,000 c/s in addition to the normally quoted figure, but in this frequency region high absorption is given by the air in the room and generally nothing is gained by giving attention to small differences in absorption co-efficients.

48. Absorbent treatments usually give most benefit in large rooms where noise sources are confined to some parts of the room only. It is normal to provide most of the absorbent material on the ceiling, this being the surface most exposed, and nearest to the noise source. The use of absorbent lined ceilings is particularly important in corridors in reducing the spread of noise about a building or department.

(4) Application of sound absorption

49. It is not easy to find suitable sound absorbent materials for use in hospital construction because of the requirements of hospital hygiene. Many sound absorbent materials are not easily cleaned and, being of a soft, porous nature, can harbour bacteria more readily than harder surfaces. However the degree to which sound absorbent materials are a danger can perhaps be over-rated. Experiments at the Public Health Laboratory Services' laboratories at Colindale with sound absorbent ceilings do not suggest that their use increases the risk of cross infection. Some porous materials with very thin non-porous coverings, for example of thin plastic, have good sound absorbent qualities and are readily cleaned, though they are not generally very robust.

50. When materials with high absorption quality are being considered other factors must be examined such as maintenance and their fire resistant qualities. On the latter, reference should be made to Hospital Design Note No. 2, Protection against Fire, and the need for incombustible and low flame spread linings.

51. Selection must also be governed by the type of sound the material is intended to reduce. Absorbents may be classified in three main types according to the manner in which they function:

(*a*) Porous materials
(*b*) Resonant panels
(*c*) Cavity resonators (also known as Helmholtz resonators).

Type (*a*) absorbs mainly at middle and high frequencies, type (*b*) at low, whilst type (*c*) can be designed for maximum absorption at practically any specified frequency level.

52. Unless absorption is required only at high frequencies, porous treatments should be at least 1 in. or more thick. Acoustic tiles are generally ½–1 in. thick but are often mounted on battens which effectively increase the thickness. In examining the absorption coefficient, therefore, attention must be given to the method of mounting used in the test or specified.

53. Resonant panels have maximum absorption in the range of 50 c/s–200 c/s and are consequently not particularly suitable for noise reduction in hospitals. Cavity resonators are only efficient over a very narrow frequency band, and are equally not applicable to most noise problems. Some composite constructions are made which combine to some extent the functions of all three types of absorbents. (For further details see British Standard Code of Practice; C.P.3. Chapter III 1960 Appendix B, paragraph 12).

C. Control of noise at source

General

54. The control of noise at its source is the first approach to any potential problem of noise. The judicious selection of plant and equipment is a fundamental of this approach combined with good installation practice and correct operation and maintenance.

55. The following paragraphs outline some of the sources of noise in hospitals, and indicate some simple measures which can be taken to control the transmission of noise and vibration.

56. Whilst each item is discussed individually, in practice a number may be installed in any one plant room associated with the various environments served. It is, therefore, the overall noise potential which must be considered by the hospital designer and to make this possible manufacturers of plant and equipment should be asked to provide an octave band analysis indicating the sound power level of their product in appropriate cases, defining the conditions of test.

57. Reference should be made to Hospital Technical Memoranda Nos. 7, 8 and 11 dealing with sub-stations, transformers, switchroom, generators and motors, and electro-medical apparatus.

58. Appendix VIII sets out some recommendations of the U.S. Department of Health, Education and Welfare on sound pressure and sound power levels for plant and equipment.

59. So far the Ministry has not recommended design criteria of acceptable noise levels for hospitals as a whole. There are many factors that have to be taken into account before deciding what is acceptable for a given situation. For example the background noise of a site is an important factor. A quiet rural hospital where quite low levels of noise are intrusive will require a better standard of noise control than a similar hospital on a noisy urban site. There are also other factors such as whether a noise is continuous or intermittent, and the differences of acceptability between staff and patients, etc.

60. There have been no detailed studies completed on what noise levels are tolerable in hospitals. The Ministry is however financing the Bartlett School of Architecture, University College, London, to carry out a study on exterior noise levels and their acceptability or otherwise in different hospital situations. It is hoped that this study will enable more definitive guidance to be given in future and that further studies will be undertaken on the total noise environment.

61. However, in order to provide interim guidance it is recommended that a noise criteria rating should be followed for noise sensitive areas in a hospital. The National Physical Laboratory has described noise criteria ratings which take into account the sensitivity of the human ear to different noise frequencies. These have been described in *The Control of Noise*, published by H.M.S.O., price £1 12s. 6d. net. Included in Appendix IX of this Design Note is a graph which plots noise criteria curves against waveband frequency. It is proposed that a noise criteria rating of 35 should be adopted for noise sensitive areas, for example bed areas, consulting rooms, minor operating theatres, treatment and delivery rooms, X-ray rooms and class-rooms, etc. For major operating theatres the N.R. should be 30. As stated in paragraph 59 the noise control will vary according to local circumstances and it is therefore recommended that in using the above rating a tolerance of plus or minus 5 should be adopted to take account of differences of background noise, etc.

(*1*) *Engineering plant and services*
Boiler house and associated equipment
Boilers

62. Some noise is usually emitted from the boiler itself, caused by steam blow-down and associated drainage and also from the combustion chamber, particularly when oil is the fuel medium. In the case of oil burning, the noise generated is predominantly low

frequency and can be most annoying even some distance away from the boiler house.

Oil burners

63. Some types of oil burners can be particularly noisy and relative noise production should be taken into account when selecting both boiler and burner for new installations. Where blower type fans are proposed the air inlet can often be effectively silenced by the use of an acoustic box or by siting the air-intake in a screened position. In some cases the air-intake can be connected to the floor trench system accommodating oil pipe work and utilising the system as a duct for the air supply to the burners.

Oil storage tanks

64. Oil storage tank filling connections should be sited away from "quiet zones" to avoid disturbance when deliveries are made.

Mechanical stokers

65. Buckets, scraper-conveyors, tipping gear, etc. should be enclosed as far as practicable, and facilities should be provided for adequate oiling of all moving parts. Rubberised conveyor belts are less noisy than scraper-chains.

Pumps

66. Particular care should be taken with the installation of boiler feed and condensate return pumps and piping, to avoid water hammer and cavitation, since these can cause severe noises in associated pipework. It is essential that:

(i) if electrically driven their motor speed should not, generally, exceed 1,000 revolutions per minute;

(ii) they are secured on resilient mountings;

(iii) flexible connections are provided between all pumps and headers or piping, and

(iv) steam-driven feed pump exhausts should be fitted with an approved type of silencer.

Ventilation and extract fans

Centrifugal fans

67. Fans of the centrifugal type used for induced draught, forced draught, air supply and exhaust, are often noisy. Backward curve fans should operate near the point of maximum efficiency, and forward curve fans at the point of maximum efficiency. The following precautions are usually necessary:

(i) the fans should be fixed on suitable insulated bases or on resilient mountings;

(ii) they should be designed in relation to the friction line of the duct installation to ensure that they operate on a stable portion of the fan's characteristic curve;

(iii) the fan housing should, if necessary, be insulated;

(iv) suitable bracing should be provided to prevent drumming;

(v) the tip speed of the impeller should be kept within the limits of good design and the fan motor speed should not generally exceed 1,000 revolutions per minute in noise-sensitive areas;

(vi) flexible sleeving or jointing should be inserted between the fan and ductwork as a standard practice;

(vii) the mean air velocity at discharge will depend on where the fan operates; for very quiet operation, in operating theatres and other noise sensitive areas, a velocity of 1,000/1,200 feet per minute should not be exceeded, and for other applications it should not normally exceed 1,500 feet per minute. Some fan discharge velocities may exceed 1,500 feet per minute, but in these cases a silencer will invariably be required to attenuate noise. When choosing a centrifugal fan preference should be given to the model which, in addition to complying with the above requirements, has *the lowest sound rating value.*

Axial flow fans

68. These fans should operate at an efficiency of not less than 80 per cent. Resilient mountings will generally be provided as an integral part of the fan support. Streamlined fairings assist smooth running and reduction of vibrations. For most applications this type of fan will need to be fitted with a silencer to attenuate noise. Exceptionally, the larger units may not require a silencer.

Propeller fans

69. If air noise from these fans is to be avoided, the tip speed should be less than 4,000 lineal feet per minute. When the air is allowed a free discharge it should be directed away from any nearby noise sensitive area, particularly wards. Sufficient distance should be allowed between the fan and weather louvres to avoid risk of obstruction to the air flow.

Ventilation ductwork

70. Ventilation ducts are potentially very efficient paths for the transmission of noise. Noise may enter the duct system from outside the building through the main inlet or extract openings and travel against the main airflow: or it may enter from inside the building either through the ventilation openings or direct through the duct wall since normal metal ducting has an insulation value of only about 20 dB, expressed as a sound reduction factor: or it may be generated within the duct system itself by fans, motors, etc. In hard-surfaced ducts noise can travel long distances with very little attenuation, and penetrate every ventilation opening and through duct walling.

71. The reduction of noise per unit length along a duct is a constant and can be calculated. It is very small for unlined ducts but some attenuation is given by sharp

bends if the duct dimensions are larger than about 1 wavelength of the sound concerned. For appreciable noise reduction a length of the duct should be lined with good sound absorbing material; in the case of large ducts it may be necessary to sub-divide into smaller channels by the use of sound absorbent splitters. For a given length of treatment, and with the proviso given above, bigger dividends are given by lining a length that contains a bend.

72. It is important at the design stage to select suitable air velocities in order to minimise noise transmission. Mean air velocities in ducts should generally be carefully graded. Although small ducts may transmit less noise than large ducts, high velocities cause more noise than lower velocities. Air velocities in the region of 1,000 feet per minute are usually satisfactory. High velocity systems are very much in excess of this datum, however, and special precautions to achieve acceptable sound levels are necessary. Such precautions are the lining of ducts with acoustic material suitably sealed and enclosed to prevent small particles from being carried along the ducts; also the provision of silencers and baffles. It should be noted that silencers, baffles or linings must always be provided where there is a change from high to low pressure, e.g. in attenuator boxes before grilles.

73. Ventilation systems should be designed to avoid air turbulence, which can produce wind and resonance noises. Grilles and diffusers should generally be of the directional pattern, carefully selected from makers' catalogue data regarding neck velocities, "throw" and their noise values. Generally, the face velocity of air across the free area of grilles should not exceed 400 feet per minute.

74. The sound insulation of the duct walls must be adequate at every point to sustain the sound reduction achieved via other paths, unless this latter reduction is in excess of requirements. The insulation value of the duct wall need not therefore be constant throughout its length. Where they pass through the walls and floors, ducts should be isolated from the building structure by felt, cork or similar insulation. All holes around ductwork should be packed with suitable sound-absorbent and fire-proof material. Fire dampers should be provided across ducts at points where they pass from one fire-compartment to another; in addition, the packing round the ductwork will be required to have a fire resistance equal to that of the compartment wall.

75. Ductwork should be suitably braced or stiffened to prevent drumming; if suspended from ceilings it may rest on sponge rubber or felt-lined supports to prevent mechanical vibration being transmitted to the structure. Badly fitted joints in ductwork will cause noise even at comparatively low velocities.

76. Noise reduction in ventilation systems is dealt with in British Standard Code of Practice, C.P. 352 "Mechanical ventilation and air conditioning in buildings".

Pipework for mechanical services

77. In order to prevent vibration from equipment being transmitted via pipework it may be necessary to support the larger pipework with resilient hangers. Modern multi-storey buildings require hot and cold domestic water to be pumped to high levels. Considerable noise can be transmitted from the risers, unless they are insulated from the structure of the building; in some instances it may be necessary to insulate the pipes. High velocities should be avoided. Generally, a water flow not exceeding 4 feet per second is satisfactory, though this may be increased to 6 feet per second in the larger pipe sizes (3 in. diameter and above).

78. Low velocities for steam flow in pipes should be allowed at design stage. Average velocities may vary between 50 and 100 feet per second. Steam traps, automatic air vents, and condensate lifting traps fitted to pipework should be specifically designed to prevent escape of steam or condensate, to minimise noise. If possible, the installation of steam traps and reducing valves should be avoided in noise sensitive areas. If this is not possible such plant should be properly insulated. The discharge point of steam and condensate should be sited away from noise sensitive areas. Boiler "blow-down" piping should be firmly anchored but provision should be made for expansion. The boiler escape valve "blow-off" should be provided with a suitable terminal and be fitted with a silencer when the boiler house is sited adjacent to wards or residential accommodation. Water hammer in steam systems may be reduced if all connections to steam mains are taken from the top of the pipes, the piping laid to fall in the direction of steam flow, and the pipework provided with adequate drain points. Exceptionally, it may be necessary to operate at reduced pressure or to install air vessels in suitable positions.

Diesel driven stand-by electric generators

79. These are sometimes in or adjacent to the boiler-house, but they may also be in a suitable room within the hospital building and thus near noise sensitive areas. Noise may be caused by the engine exhaust (a silencer should be fitted), and by mechanical noise from the engine and housing; to combat this within sensitive areas the room containing the generator should have good insulation. To lessen noise caused by vibration the generator-set should be mounted on a concrete plinth of adequate mass and rest on suitable resilient foundations designed to damp out the vibrations. Insulation may be required around the block to prevent the transmission of lateral vibration. Ventilation should be provided to the room to allow the set to operate satisfactorily without opening doors or windows. Care should be taken in the positioning of the air intake and exhaust.

Air compressors

80. Air compressors both of the reciprocating and rotary vane type generate considerable noise. It is preferable to site compressors away from the main hospital building; where two or three larger compressors

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are placed together it may be necessary to provide a wall of suitable thickness to act as a screen or baffle between the doors of the compressor room and the rest of the hospital. Mechanical noise from the compressor shell and the transmission of vibration to the building structure from pipework can be avoided by the following precautions:

(i) the set should be mounted on a concrete block of adequate mass and placed on suitable resilient foundations;

(ii) the intake should be fitted with an efficient silencer; large reciprocating compressors can set up high levels of subsonic noise, not attenuated by ordinary silencers, which may well rattle windows and doors in the vicinity. Special measures would be needed to reduce this noise;

(iii) pipework and conduits should be fitted with flexible connections to break metallic continuity.

Transformers within the hospital building

81. Electrical transformers are often sited in rooms or chambers within the hospital building. Although they are stationary, they generate a low frequency hum, which, while hardly noticeable during the day can be very annoying at night. Transformers should be mounted on resilient mountings, and vents should be fitted with silencer ducts to limit the escape of noise and to attenuate the low frequency sounds. Where louvres alone are thought to be satisfactory they should deflect the noise in a downward direction away from occupied areas.

Switch rooms within the hospital

82. These are sited in many areas within the hospital building for electrical distribution purposes. Noise from switch-gear, contactors, relays, etc. may be transmitted through walls and openings unless the following points are considered:

(i) free-standing or wall-mounted switchboards should have suitable resilient mountings;

(ii) open louvres fitted to doors and walls for ventilation should be avoided;

(iii) the use of direct-current operated coils with "in-built" rectifiers in contactors.

Lifts

83. Lifts should operate quietly and without vibration. They should, preferably, have electro-mechanically operated doors, with rubber buffers, when sited adjacent to noise-sensitive areas. Expanding metal gates are usually excessively noisy and their use should be avoided if possible, or strictly limited to service areas. The motor room is better sited on the roof than in the basement and internal entrance doors should be well fitted. The lift machine and motor-generator (if fitted) should be insulated from the building by resilient mountings. The reversing control gear should be enclosed. The worm gearing should be enclosed and run in an oil bath. Anti-friction sleeve bearings or roller-bearings should be provided and have easy means of lubrication. Guide-rail lubricators should be installed on top of the car and counter-weight.

Main kitchen mechanical equipment

84. Generally, the main kitchen should be sited away from the wards and other noise sensitive areas. Some of the machines causing noise are dishwashing machines, food mixers, steam ovens, vegetable-parers, refrigerators, and extract ventilation plant. The installation of fans and ventilation ductwork should follow the principles laid down in paragraphs 67–76.

Vacuum pumps

85. These often cause a noise nuisance when running during operations, and due care should be taken when a selection is made.

Pressure steam sterilisers

86. These machines cause airborne and structure borne noise when working. It is recommended that:

(i) the vacuum pump and motor assembly be fixed on separate resilient mountings. If the steriliser is situated within the T.S.S.U. or C.S.S.D. it may be necessary to provide a sound insulation jacket for the vacuum pump assembly.

(ii) The whole steriliser assembly be secured on resilient mountings such as springs or cork and isolated from the floor of the building.

(iii) All pipe connections to the steriliser, e.g. for steam, water, vacuum, compressed air, and condensate should be of the flexible type.

(iv) Open louvres in doors and walls of the sterilising rooms should be avoided, and doors should be self-closing and well sealed. Steam and heat are given off in the sterilising room and it is important that adequate ventilation be provided to remove this heat.

Ultra-sonic washers

87. These cause severe annoyance to staff working in the vicinity and due care should be taken in their location and installation.

Laundries

88. Noise from laundries is caused by the loading and unloading of linen, calendering machines, drying tumblers, presses, ventilation systems, conveyors, air compressors, and other equipment. Most of the noise will be airborne through open windows, doors and louvres. Since, however, the laundry is usually grouped near the boiler-house and remote from sensitive areas, this siting (together with careful positioning of unloading bays, doors, etc.) will usually be sufficient to reduce laundry noise to an acceptable level. In the case of air compressors, however, the precautions outlined in paragraph 80 may be needed.

Cisterns

89. Silencing pipes and quiet flushing devices should

be fitted to all cisterns in ward areas. Measurements of noise-levels recorded in w.c's. are given in Appendix X.

Communications

90. Low sounding buzzers are now in use for patient/nurse call systems and these buzzers are not usually sited in rooms or bed areas, but elsewhere in the ward. In all but the smallest wards the practice of providing only one buzzer at a central point generally necessitates a sound level which is disturbing to patients in the immediate vicinity, and it is usually desirable to install a number of buzzers of lower volume at intervals in the ward unit to provide the coverage required. All buzzers should be muted at night, provided that the visual or other call indicators remaining in circuit are arranged to give full coverage of the ward. For further advice on patient/nurse call systems see Hospital Technical Memorandum No. 15. Telephone bells should be carefully sited away from patients; quiet bells (damped) with a night switch and low frequency buzzers should be used.

91. Radio and television sets used in day spaces and private wards should have the sound coming from the front rather than the side so that the volume need not be so high. Satisfactory ear phones have been developed for use in wards. In open type wards it is suggested that the "sound" for TV is wired through patients' headsets only, and *not* through the loudspeaker on the set.

Electric refrigerators

92. Larger refrigerators of the reciprocating type associated with cold store and air conditioning plant often cause noise. The noise which is caused by the stopping and starting of the compressor can be overcome by fixing the set on suitable resilient mountings and reducing fan noise. For domestic refrigerators for use in, e.g. ward pantries and the pharmacy department, relatively quiet machines should be selected. Hermetically sealed compressors in suitable enclosures with quiet motors are now available for this type of refrigerator, but, exceptionally, where extremely quiet operation is required, the absorption type may be necessary.

Bed-pan washers

93. Bed-pan washers should be selected for their quiet operation as some of these machines can reach a level of 90 dB. Correct steam pressures and valve sizing can, however, minimise the sound emitted. Machines dealing with disposable bed-pans are now being used. These may reach 78 dB, reducing to 71 dB in a two-minute cycle. It is essential in all cases that there should be good sealing arrangements of the cabinet and components for reasonably quiet operation. Care should be taken to provide flexible joints between the washer and the service pipes, including the drains.

Cleaning equipment

94. These machines fitted with silencers are fairly quiet in operation if properly maintained and serviced.

(2) *Miscellaneous equipment*

Trolleys

95. Dressing trolleys and cleaners' trolleys should have good quality rubber tyred wheels or castors of at least 4 in. diameter. Trolleys with fixed shelves are generally less noisy than trolleys with loose shelves; where loose shelves are used rubber buffers supporting the shelves must be kept in good condition and in the correct position on the frame. For patients' trolleys castors should be larger—at least 7 in. and preferably 9 in. in diameter.

Patients' beds

96. Patients' beds should have castors with rubber treads. They should be in accordance with B.S. 1682: 1950, i.e. $\frac{7}{8}$ in. wide by 4 in., or 1 in. wide by $5\frac{1}{2}$ in.

Bins and buckets

97. In noise sensitive areas, vulcanised or plastic bins and buckets of hygienic type should be used.

Utensils

98. Nylon, polythene, or polypropylene utensils and trays can often be used for both domestic and medical purposes in place of metal ones, providing there is no objection to them on other grounds.

Sinks

99. Steel sink units are noisy but this can be minimised if they are coated on the underside with rubberised paint.

Bed curtain tracks

100. Silent type curtain tracks should be fitted to prevent noise caused by the pulling of bed curtains.

Oxygen

101. The movement and changing of oxygen cylinders is often a major cause of disturbance. Noise can be minimised if resilient surfaces in reception areas are provided and if modern trolleys with large rubber wheels and padded frames are used. The problem can be resolved if economic considerations permit the installation of piped oxygen.

Other sources of information

102. Other recommendations concerning the control of noise are to be found in "Control of Noise in Hospitals", the Report of the Standing Nursing Advisory Committee sent to hospital authorities under cover of H.M.(61)68 and in the reports of the King Edward's Hospital Fund for London on Noise Control in Hospitals published in 1958 and 1960.

APPENDIX I

Terms used in this Design Note

Sound

Sound may be produced by a vibration if the vibration is within the audio frequency range and the magnitude of the sound is above the threshold of hearing.

The audio frequency range covers about 9 octaves and over a frequency of approximately 20 to 20,000 cycles per second but on average the human ear responds to frequencies within the range of 25 to 15,000 cycles a second.

Noise

Noise is defined as sound which is undesired by the recipient so that, for noise sensitive areas in hospitals, noise should be defined as "unwanted sound".

Transmission

Transmission of sound requires some media–either solid, gas or liquid as transmission paths from the source of the sound to the receiver. As such, noise may be transmitted as a vibration from machinery to the structure of a building; it may be airborne, e.g. fan noise or as air turbulence in air distribution ducts; or waterborne, e.g. noise from pump impellers, or water turbulence.

Reception

Reception of sound can only be assessed subjectively so far as human reactions are concerned. It depends not only on frequency and magnitude but also on the physiological and psychological state of the listener as well as the circumstances in which the sound is heard. A patient, as a "captive audience", may be distressed by a sound which might well go unnoticed or be regarded only as slightly annoying by members of hospital staff in the vicinity.

Magnitude

Magnitude of sound is expressed in terms of sound pressure level, sound intensity level, or sound power level, dependent on the information required. To indicate these levels in absolute values would be unwieldy because the figures involved are large and in practice it is more convenient to use the indices of these figures in terms of logarithms. The quantity so obtained is the bel but in acoustic work one-tenth, i.e. the decibel, is more appropriate as the bel is considered to be too large.

The decibel is dimensionless, it is a logarithm of a ratio which expresses the relative magnitude of sound as compared to the level for the reference selected.

The references usually adopted are:

0.0002 dynes/cm^2 or 0.00002 Newtons/m^2 for sound pressure level (Lp)
10^{-16} Watts/cm^2 for sound intensity level (Li) and,
10^{-12} Watts/cm^2 for sound power level (Lw)

The sound pressure and sound intensity vary in relation to the location and circumstances of measurement but the sound power emitted from a source is constant.

Sound power level cannot be measured but must be derived from considerations of sound pressure level which is directly measurable. Acoustic design is based on sound power level and it is advisable therefore to obtain levels in terms of sound power for new plant and equipment where information of potential noise is required.

Measurement

Measurement of sound (noise) is carried out by a sound pressure level meter and almost invariably in conjunction with some form of frequency analysis equipment, usually octave or $\frac{1}{3}$ octave band-pass filters. Meters may incorporate frequency response weighted to provide readings to correspond approximately to the reaction of the human ear to sounds of different intensities; these are known as sound level meters, the A scale is the most usual and is adopted in this note and readings from meters so weighted are given as dBA. Some sound level meters incorporate, or can readily be used with associated, octave band filters to give broad band analysis when comparison with recommended noise criterion is to be made.

Loudness

Loudness is a subjective appraisal of the sensation of the strength of a sound. The unit is the "phon" and, based on a consensus of opinion of average reactions, "equal loudness" curves have been developed.

APPENDIX II

Range of noise levels at locations in which traffic noise predominates

In 1961 and 1962 the Building Research Station, the London County Council and the Central Office of Information carried out a special investigation of the noise levels at 540 points equally spaced over 36 square miles of Central London, and of the reactions of the inhabitants to the noise. Preliminary information on the analysis of the results from about 400 points of the survey was supplied to the Committee on the Problem of Noise who were appointed in 1960 by the Minister for Science "to examine the nature, sources and effects of the problem of noise and to advise what further measures can be taken to mitigate it". The most important conclusion to be drawn from this preliminary information was that at 84 per cent. of the points noise from road traffic predominated: at these points the noise level varied considerably with the district and with the time of day, as is shown by the following table which is reproduced from Chapter IV of the Report of the Committee entitled "Noise" (H.M.S.O. 13s net):

Group	*Location*	*Noise climate (in dBA)**		*Percentage of the total numbers of points measured falling in each group*
		Day (8 *a.m.*–6 *p.m.*)	*Night* (1 *a.m.*–6 *a.m.*)	
(*i*)	(*ii*)	(*iii*)	(*iv*)	(*v*)
A	Arterial roads with many heavy vehicles and buses (kerbside)	80–68	70–50	4
B	(i) Major roads with heavy traffic and buses (ii) Side roads within 15–20 yds. of roads in Groups A or B(i) above	75–63	61–49	12
C†	(i) Main residential roads .. .. .. (ii) Side roads within 20–50 yds. of heavy traffic routes .. .. (iii) Courtyards of blocks of flats, screened from direct view of heavy traffic	70–60	55–44	17
D	Residential roads with local traffic only	65–56	53–45	18
E	(i) Minor roads .. .. (ii) Gardens of houses with traffic routes more than 100 yds. distant	60–51	49–43	23
F	Parks, courtyards, gardens in residential areas well away from traffic routes	55–50	46–41	9
G	Places of few local noises and only very distant traffic noise	50–47	43–40	1
				84%

* By noise climate is meant the range of noise level recorded for 80 per cent. of the time. For 10 per cent. of the time the noise was louder than the upper figure of the range and in the case of Group A attained peak levels of about 90 dBA: for 10 per cent. of the time the noise was less than the lower figure in the range.

† In Groups C to F, noise from other sources, such as trains or children's voices, predominated over road traffic noise at particular times, but traffic was the most frequent noise source.

APPENDIX III

Some noise sources to be considered in the design of hospitals

Stage of Design Team operations	*Source*	*Points to be considered*
A Proposed location of development	Airport	Noise from: (1) Operational aircraft on ground. (2) Aircraft landing and taking off. (3) Aircraft maintenance areas. (4) Air traffic lanes. (5) Whether preferential runway system available. (6) Any extensions envisaged. (7) Any alterations to runways likely.
	Road traffic outside boundary of hospital development	Existing level and noise climate. Future traffic or highway engineering proposals.
	Rail traffic outside boundary of hospital development	Existing level future proposals.
	Industry outside boundary of hospital development	Existing level—Night time operations. Future development proposals in area.
B Development control plan	Sources within the development	(*a*) Noise producing areas, e.g. Laundry, Boiler House, Workshops, Car parks, C.S.S.D., kitchens, etc. (*b*) Supply and service routes external to buildings housing noise sensitive areas.
C Sketch drawings (Scheme design)	Sources within the development	Plant rooms. Departments in vicinity of noise sensitive areas. Plant and equipment in ancillary accommodation serving noise sensitive areas. Equipment proposed for use in the noise sensitive areas. Effect of internal supply and service routes and their associated equipment.

APPENDIX IV

Typical noise levels of contractors' plant

Type of plant (*i*)	*Sound level dBA at 50 feet* (*ii*)	*Type of plant* (*i*)	*Sound level dBA at 50 feet* (*ii*)
Unmuffled concrete breaker	85	Petrol poker vibrator	64
Muffled and screened breaker	65	Electric poker vibrator	71
4 tool diesel compressor	73	10/7 diesel concrete mixer	75
4 tool electric compressor	73	10/7 electric concrete mixer	61
Petrol concrete breaker	76	Earth auger driven from diesel tractor ..	66
Rock drill	87	Hand held tree saw	82
Thermite tool	62	¾ cu. yd. dragline	74
180 h.p. Angledozer	83	1½ cu. yd. dragline	78
90 h.p. Angledozer	74	300 c.f.m. reciprocating diesel compressor	77
1½ cu. yd. tractor shovel	76	600 c.f.m. rotary diesel compressor ..	79
Rubber tyred tractor-scraper	93		
30 cwt. dumper	75		
4 cu. yd. concrete carrying vehicle ..	75		

NOTES:

(i) The noise levels quoted are with the machines operating normally, and fitted with exhaust silencers where appropriate.

(ii) The levels given in the table each relate to one particular item of equipment at the specified distance, 50 ft. Two machines, each individually producing the same level, when operated at the same time give an increase of 3 dB and with 3 equally noisy machines the corresponding figure is 5 dB. If one machine is markedly noisier (6–10 dBA) than the other, the total noise level is not significantly increased when the quieter machine is added.

(iii) The effect of halving or doubling the distance from the machine is to add or subtract 6 dB from the measured level, e.g. an unmuffled breaker at 25 ft. would be 91 dBA and at 100 ft. 79 dBA. Reflections from adjacent buildings can increase the noise level by a few dB compared with levels measured under open conditions.

This table is reproduced from "Noise", The Report of the Committee on the Problem of Noise (Cmnd. 2056): Chapter X—Noise from Construction and Demolition Sites (H.M.S.O., 13s net).

APPENDIX V

Effect of window size on the insulation of walls

Sound insulation values of a 9 inch brick wall with different percentage areas of window; the figures are for closed windows, single and double, taken from the table given in Appendix VI.

Percentage of glazing	*Single window*	*Double window*
	dB	*dB*
100	20	40
75	21	41
50	23	43
33⅓	25	44
25	26	45
10	30	47
Nil	Value of a 9 inch brick wall — 50 dB	

NOTE. The single window is assumed to be openable, and the double window sealed and glazed with 32 oz glass on both sides of an 8 inch air-space having absorbent lined reveals. If 10 per cent. or more of the wall is open window, the insulation will not be more than 10 dB. It is seen from the table that the range of percentages of glazing from 10 per cent. to 100 per cent. produces a range of variation of the insulation of 10 dB for single windows and 7 dB for double windows. The more important glazing range from 25 per cent. to 75 per cent. produces an insulation variation range of 5 dB for single windows and 4 dB for double windows.

Insulation values of partitions with doors

Construction	*Insulation value of partition*					
	25 dB	30 dB	35 dB	40 dB	45 dB	50 dB
Any door with large gaps round edges	23	25	27	27	27	27
Light door with edge-sealing treatment	24	28	30	32	32	32
Heavy door with edge-sealing treatment	25	29	33	35	37	37
Double doors with soundlock (air-space or lobby)	25	30	35	40	44–45	49

NOTE. The table is based on the assumption that the area of the door is about 7 per cent. of the area of the partition in which it is incorporated.

Source: These tables are reproduced from British Standard Code of Practice C.P.3: Chapter III (1960), "Sound Insulation and Noise Reduction", by permission of the British Standards Institution, 2, Park Street, London, W.1, from whom copies of the complete Code may be purchased.

APPENDIX VI

Approximate sound insulation values of single and double windows

Construction	*Approximate sound insulation*
	dB
Wide-open window	About 5
Slightly open single window	10–15
Closed "openable" single window	18–20
Sealed single window (24–32 oz. glass)	23–25
Sealed single window (¼ inch plate glass)	27
Sealed single window (⅜ inch plate glass)	30
Ventilated double window (5 per cent. area of "indirect" ventilation)	15–20
Closed "openable" double window (any weight of glass, with an air-space of 8 inches and absorbent-lined reveals)	30–33
Sealed double window (32 oz. glass with an air-space of 8 inches and absorbent-lined reveals)	40
Sealed double window (¼ inch plate glass with an air-space of 8 inches and absorbent-lined reveals)	42
Sealed double window (32 oz. glass one side and ¼ inch plate glass other side, 8 inch air-space and absorbent-lined reveals)	42–43

Source: As for Appendix V.

Insulation value of different wall constructions

Single-leaf walls or partitions

Construction	Approx. *weight*	*Average sound reduction* (100–3,200 *c/s*)
	lb/ft²	*dB*
2 in. wood-wool slab plastered ½ in. both sides	14	35
3 in. hollow clay block with ½ in. plaster both sides	22	36
4 in. hollow clay block with ½ in. plaster both sides	25	37
2 in. clinker block with ½ in. plaster both sides	22	37–38
3 in. clinker block with ½ in. plaster both sides	30	41
4 in. clinker block with ½ in. plaster both sides	38	43
8 in. hollow clinker block with ½ in. plaster both sides	35	42
8 in. hollow dense concrete block with ½ in. plaster both sides	50	45
4½ in. brick with ½ in. plaster both sides	55	45
9 in. brick with ½ in. plaster both sides	100	50
7 in. dense concrete with ½ in. plaster both sides	95	50
10 in. dense concrete with ½ in. plaster both sides	130	52

Double-leaf walls or partitions

Construction	*Approx. weight*	*Average sound reduction* (100–3,200 *c/s*)
	lb/ft²	*dB*
* Double 2 in. clinker block with 2 in. cavity. Thin wire ties. ½ in. plaster both sides	38	47
* Double 2 in. clinker block with 6 in. cavity. No ties. ½ in. plaster both sides	38	50
* Double 3 in. clinker block with 2 in. cavity. Thin wire ties. ½ in. plaster both sides	50	49
* Double 3 in. clinker block with 3 in. cavity. Thin wire ties. ½ in. plaster both sides	50	50
* Double 4 in. clinker block with 2 in. cavity. Thin wire ties. ½ in. plaster both sides	64	50
* Double 4½ in. brick with 2 in. cavity. Thin wire ties. ½ in. plaster both sides	100	50–53
* Double 9 in. brick wall with 2 in. cavity. No ties. ½ in. plaster both sides	190	55
† 4 in. Double skin plasterboard (with or without quilt)	7	43–45
† 4 in. Single skin plasterboard	5–6	36–40

Source: *As for Appendix V (extracts only).

† Tests in 1964 by Messrs. A.I.R.O. Ltd.

NOTE: The insulation values given in this Appendix are approximate and, except for the last 2 items, represent expected values in the field (see section IIIB, paragraph 38).

APPENDIX VIII

The tables below are based on Tables 8A, 8B and 9 "Noise in Hospitals", a publication of the U.S. Department of Health, Education and Welfare, from whom permission for its use has been obtained. It gives recommended maximum average sound-pressure and sound power levels in eight frequency bands for various plant and equipment.

TABLE 1

Recommended maximum average sound-pressure levels*

For machines with maximum dimension of less than 6 feet

Sound-pressure levels are to be measured at 6 feet from each machine in at least five positions on each side and above and below (if machine does not sit on floor). Readings shall be averaged arithmetically, except that all readings more than 10.0 decibels below the maximum reading shall be disregarded in taking the average.

Frequency band, cps	*Sound-pressure level re* 0.0002 *microbar*								See note 1 overleaf
	20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–9600	
Schedule I ..	60	51	43	37	32	30	28	27	
Schedule II ..	63	55	47	41	37	35	33	32	
Schedule III ..	75	68	64	64	64	64	64	64	
Schedule IV ..	100	95	91	87	84	82	82	82	

TABLE 2

Recommended maximum average sound-pressure levels*

For machines with dimension of 6 feet or more

Sound-pressure levels are to be measured at 6 feet from each machine in at least five positions on each side and above and below (if machine does not sit on floor). Readings shall be averaged arithmetically, except that all readings more than 10.0 decibels below the maximum reading shall be disregarded in taking the average.

Frequency band, cps	*Sound-pressure level re* 0.0002 *microbar*								See note 1.
	20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–9600	
Schedule I ..	55	47	40	32	27	25	25	25	
Schedule II ..	58	50	42	36	32	30	30	30	
Schedule III ..	71	63	60	60	60	60	60	60	
Schedule IV ..	95	90	86	82	89	77	77	77	

TABLE 3

Recommended maximum sound-power levels*

Frequency band, c/s	*Sound-power levels in dB's re* 10^{-12} *watts*								See note 1.
	20–75	75–150	150–300	300–600	600–1200	1200–2400	2400 4800	4800–9600	
Schedule I ..	57	51	45	43	38	36	34	33	
Schedule II ..	62	66	51	50	46	45	44	43	
Schedule III ..	72	68	66	70	70	70	70	70	
Schedule IV ..	100	98	95	94	92	90	89	88	

* If hospital rooms do not have acoustical treatment of ¾ in. tile or equivalent on ceiling, subtract 8 decibels from all maximum sound levels.

Sound rating schedule for predominant hospital noise sources

Schedule No.	Noise source
I	Flush valves, private toilet. Room fans. Ventilation, grille, (ward, etc.)—(6 feet from grille).
II	Lift, corridor[2] Mechanical roof-type fans—(1 foot from intake). Mechanical roof-type extract fan with ductwork to toilets. Transformers—(50 feet from building). Transformers—(within building). Ventilation, grille (corridor)—(6 feet from grille).
III	Dish washers. Flush valves, (corridor toilet). Steam sterilisers—(steam cycle). Refrigerator—(kitchen or pantry).
IV	Boiler house equipment[3] Lift room equipment Ventilation, plant-room.

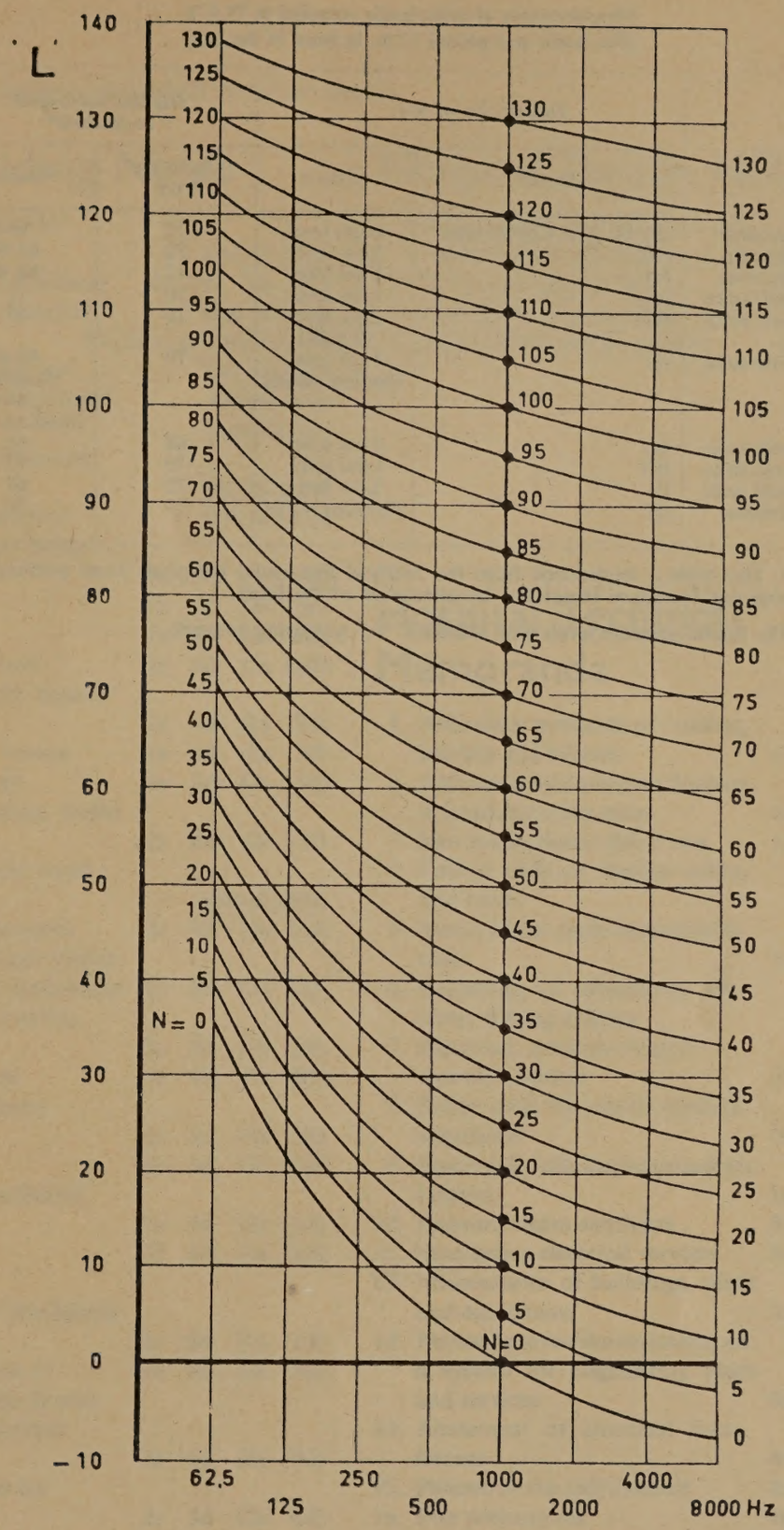
MINISTRY OF HEALTH NOTES

1. Preferred I.S.O. frequencies in cycles per second for acoustical measurements and for geometric centre frequencies of band-pass filters are: 16–31.5–63–125–250–500–1,000–2,000–4,000–8,000–16,000.
   The British Standards which refer are as follows:

   B.S. 3593:1963 Preferred frequencies for acoustical measurements.
   B.S. 2475:1964 Octave and one-third octave band-pass filters.

2. The sound measurement should be taken 6 ft. from lift doors.

3. The sound measurement should be taken 12 ft. from equipment in open air or anechoic chamber.



MIDFREQUENCY OF OCTAVE BAND (C/S)

CURVES FOR RATING NOISES FOR ACCEPTABILITY

The ordinate "L" is octave-band sound pressure level in dB relative to 2×10^{-4} dynes/cm.^{2}
These curves are reproduced from the National Physical Laboratory's publication "The control of noise" (H.M.S.O. price £1-12-6) net by permission of the National Physical Laboratory.

APPENDIX X

Measurements of noise-levels recorded in W.C's
(The meter was placed 12 in. in front of the pan)

Type	*Description of w.c.*		*Highest noise-level in decibels**	
	Model	*Cistern*	*Operating lever*	*Flushing*
Washdown	(a) Built-in Corbel type	High level	72	68
Washdown	(b)	Low level	72	64–66
Washdown	(c)	Low level	72	64–66
Syphonic suite	(d)	Low level	70	71
Syphonic suite	(e)	Low level (2 gall.)	70	65
Syphonic suite	(f)	Low level (behind panel)	70	62–63 (flushing) 64 (final suction)
Syphonic suite	(g)	Low level	68	68
Syphonic suite	(h)	Low level	70	72
Syphonic suite	(i)	Low level	72	68
Washdown	(j)	Flushing valve	—	70

Source: This table is reproduced from the Nuffield Provincial Hospitals Trust publication "Studies in the Functions and Design of Hospitals" by permission of the Trust.

* NOTE: Sound pressure levels with standard "A" weighting network.

Ministry of Health

The following hospital guidance documents have been issued:

Hospital Building Notes

1.	Buildings for the hospital service	Out of print	
2.	The cost of hospital buildings	4s 0d	(4s 6d)
3.	The district general hospital	Out of print	
4.	Ward units	Revision in preparation	
5.	Short stay psychiatric unit	Out of print	
6.	Diagnostic X-ray department	Revision in preparation	
7.	Accommodation for nursing staff	Out of print	
8.	Physiotherapy department	Out of print	
9.	Occupational therapy department	1s 3d	(1s 6d)
10.	Kitchens	2s 0d	(2s 5d)
11.	Dining rooms	1s 3d	(1s 8d)
12.	Out-patient department	1s 6d	(1s 11d)
13.	Central sterile supply department	1s 6d	(1s 9d)
14.	Training school for nurses	1s 6d	(1s 9d)
15.	Pathology department	2s 0d	(2s 5d)
16.	Boiler house and steam boiler plant	2s 0d	(2s 5d)
17.	Deep plan (race track) ward units	Out of print	
18.	Administrative department	2s 9d	(3s 2d)
19.	Department of medical photography and medical illustration	1s 9d	(2s 2d)
20.	Mortuary and post-mortem room	1s 9d	(2s 2d)
21.	Maternity department	4s 6d	(5s 0d)
22.	Accident and emergency department	4s 6d	(5s 0d)
23.	Children's ward	2s 6d	(2s 11d)
24.	Residential accommodation for staff	2s 6d	(2s 11d)
25.	Laundry	3s 6d	(3s 11d)
30.	Accommodation for psychiatric patients	1s 6d	(1s 11d)
31.	Psychiatric ward (type 1)	2s 0d	(2s 5d)
32.	Psychiatric ward (type 2) and pre-discharge (hostel type) ward	3s 6d	(4s 0d)
33.	Rehabilitation centre for psychiatric patients	2s 3d	(2s 8d)

Hospital Design Notes

1.	Dimensional co-ordination and industrialised building	3s 0d	(3s 5d)
2.	Protection against fire	2s 0d	(2s 5d)
3.	The I.H.B. programme: components and assemblies	4s 6d	(5s 0d)

Hospital Technical Memoranda

1.	Anti-static precautions: rubber, plastics and fabrics	1s 0d	(1s 3d)
2.	Anti-static precautions: flooring in anaesthetising areas	1s 3d	(1s 8d)
3.	Fire precautions: fish fryers	1s 0d	(1s 3d)
4.	Colour code of flexible cables and cords	6d	(9d)
5.	Steam boiler plant instrumentation	1s 6d	(1s 9d)
6.	Protection of condensate systems: filming amines	6d	(9d)
7.	Electrical services—supply and distribution	7s 6d	(8s 1d)
8.	Safety code for electro-medical apparatus	3s 6d	(3s 11d)
9.	Pneumatic tube communications systems	1s 6d	(1s 11d)
10.	Pressure steam sterilisers	3s 0d	(3s 5d)
11.	Emergency electrical services	5s 0d	(5s 6d)
12.	Maintenance of buildings, plant and equipment	3s 0d	(3s 5d)
13.	Planned preventive maintenance: a system for engineering plant and services	6s 0d	(6s 7d)
14.	Abatement of electrical interference	4s 0d	(4s 5d)
15.	Patient/Nurse call systems	4s 6d	(5s 0d)
16.	Fire precautions	4s 6d	(5s 0d)

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Ministry of Health Hospital guidance publications include:
Hospital Building Notes, Equipment Notes, Design Notes, Building Bulletins and Technical Memoranda

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